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Impact Of Drought On Prehistoric Western Native Americans

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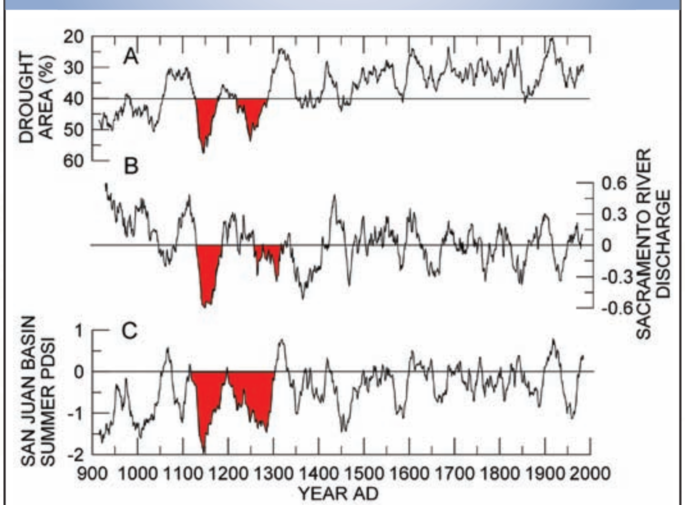
The middle-12th and late-13th century droughts

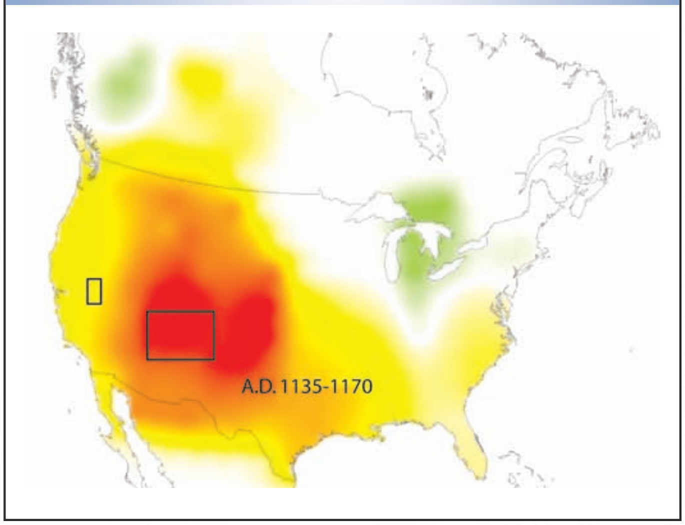
Some droughts that occurred during the so-called Medieval Climate Anomaly (approximately AD 800-1300) appear to have been catalysts for major changes in settlement patterns of two western Native American groups - the Lovelock culture in Nevada's Great Basin and the Anasazi people of the Four Corners area. Both groups' subsistence bases were impacted by diminished water supplies associated with prolonged drought, leading to the dispersal of these Native Americans from their former territories.

Figure 1
Mid-12th and late-13th century droughts
Tree-ring-based climate reconstruction for (A) drought area in the western United States (Cook et al., 2004), (B) normalized Sacramento River discharge (Meko et al., 2001), and (C) summer Palmer Drought Severity Index for the San Juan Basin (Cook et al., 2004).



Tree-ring-based Palmer Drought Severity Index (PDSI) reconstructions by Cook et al. (2004) indicate that over 50% of the western U.S. experienced drought conditions during the middle-12th and late-13th centuries (Fig. 1A, 2). Negative PDSI values indicate dry conditions, whereas positive values indicate wet conditions. This index was specifically designed to evaluate drought impacts on agriculture; PDSI values range from -6 (extreme drought) to +6 (extreme wet). During the middle-12th century drought, there existed a period of 23 consecutive years of negative summer PDSI that represents the single greatest North American megadrought since AD 951 (Cook et al., 2007). The AD 1150-1159 interval was the driest decade during the middle-12th century drought, having a North American average PDSI that was below -1.0.

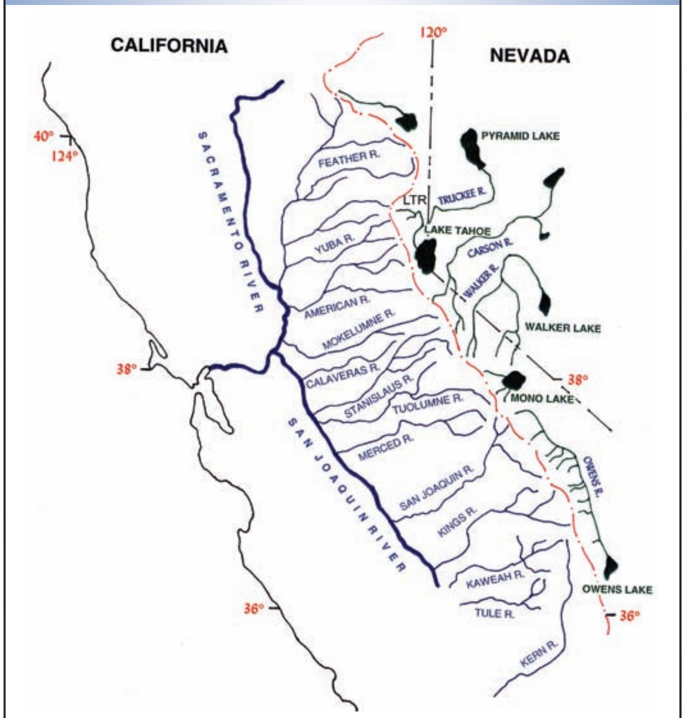
Fig. 2 Mid-12th century drought
Areal extents and intensities of the middle-12th century drought. Yellow indicates a PDSI range of -0.5 to -1, orange -1 to -2, and red -2 to -3. Green indicates a slightly positive PDSI. The large rectangle indicates the Anasazi-occupied Four Corners area; the small rectangle indicates the area occupied by the Lovelock Culture.



Drought in the western Great Basin and the Sierra Nevada

The middle-12th century droughts are evident in the Meko et al. (2001) tree-ring-based reconstruction of Sacramento River discharge (Figs. 1B, 3), in the oxygen-isotope record of Pyramid Lake, Nevada (Figs. 3, 4) (Benson et al., 2002), and in the tree-stump record of Mono Lake, California (Figs. 3, 5) (Stine, 1990, 1994). Annual discharges of rivers that drain both sides of the Sierra Nevada north of 37ºN (about the latitude of Friant Dam on the San Joaquin River) are highly correlated ($R^2 \approx 0.9$) (Benson et al., 2002); thus, if we can estimate the change in hydrologic balance that one surface-water system has experienced, we can transfer the relative degree of change to other surface-water systems in the region. Stine (1998) estimated that discharge to Mono Lake decreased by at least 40% during the middle-12th and late-13th century droughts; therefore, we can estimate the effect of such a dry period on the water balance of western Great Basin lakes and sinks that receive the majority of their inflow from streams draining the Sierra Nevada (Fig. 3).

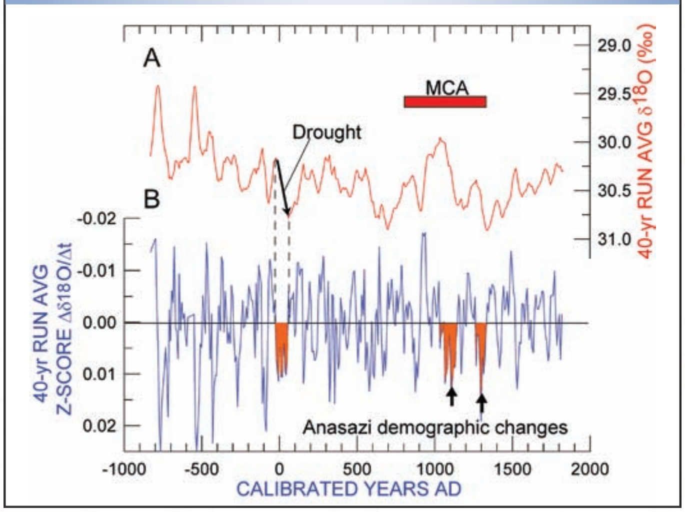
Figure 3
Sierra drainages
Surface-water systems that drain the Sierra Nevada. The Sierran crest in indicated by a red dot-dash line. The Little Truckee River is denote by LTR.



Impact of drought in Nevada's western Great Basin

If the inflow to Lake Tahoe were to decrease by 40%, Lake Tahoe would cease spilling to the Truckee River and, as a consequence, 32% of the input to the mainstream Truckee River would be lost (Benson et al., 2002). In addition, if the Little Truckee drainage (Fig. 3) that provides about 70% of mainstream Truckee discharge would be also reduced by 40%, the mean-annual discharge reaching Pyramid Lake would be decreased by at least 60% (Benson et al., 2002). Such an intense drought would eventually result in a reduction in the surface elevation of Pyramid Lake by 77 m; i.e., Pyramid Lake would go from a situation in which it naturally spilled to the adjacent, and presently dry, Winnemucca Lake basin to a situation in which it was hydrologically closed and relatively shallow (45 m). In 1913, when Pyramid Lake was spilling to the Winnemucca Lake basin, it had a volume of 37.1 km^3 and a total dissolved solids (TDS) concentration of 3920 mg/L (Jones, 1925). If during drought, that volume were reduced to 6.1 km^3 (volume at 45-m level), the TDS concentration of Pyramid Lake would increase to 23,700 mg/L. Under these conditions, Pyramid Lake would resemble present-day Walker Lake; i.e., it would turn over in the summer and winter and the native cutthroat trout fishery would fail. In addition, Winnemucca Lake would desiccate within two decades (It did so historically between 1906 and 1939 as a consequence of the partial diversion of Truckee River water to the Carson Desert) (U.S. Geological Survey, 1960). Thus, wetland-adapted Native Americans, dependent on the Pyramid Lake-Winnemucca Lake complex, would have their subsistence base greatly reduced. In addition, it is highly probable that both the Carson and Humboldt Sinks not only would have been reduced in area, but also would have frequently desiccated by the end of the autumn.

Figure 4
Pyramid Lake Oxygen-18 record of drought
(A) Oxygen-18 (18O) record from a sediment core taken in the center of Pyramid Lake, Nevada. When the volume of water discharged to Pyramid Lake by the Truckee River exceeds the volume lost due to evaporation, the 18O value decreases, and vice versa. (B) The derivative of the normalized (Z-scored) 18O value. The Z score of a value is the value minus the mean of the population divided by the standard deviation of the population. When the derivative is positive, lake level is falling. Droughts are associated with such positive values. MCA refers to the Mediaeval Climatic Anomaly.



The possible impact of drought on the Great Basin Lovelock Culture

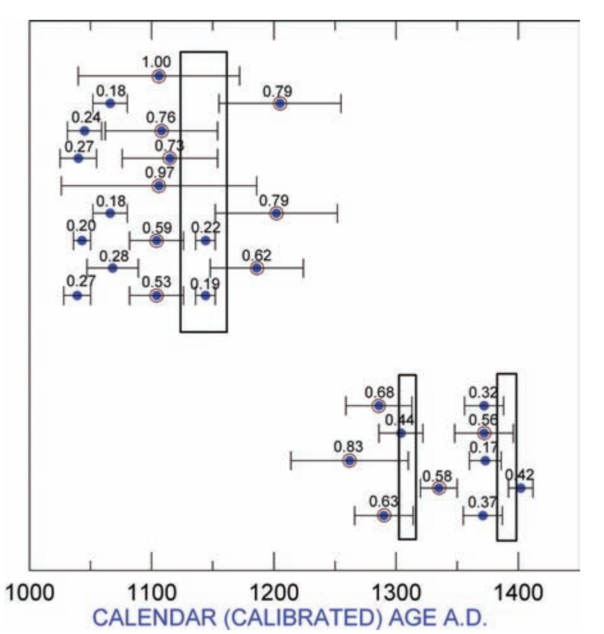
The prehistoric Lovelock Culture was initially defined on the basis of cultural deposits excavated by Loud and Harrington (1929) at Lovelock Cave, Nevada (Fig. 6).
The Lovelock people were hunter-gatherers who lived adjacent to the large terminal lakes/marshes of the western Great Basin, and who relied on the fish and waterfowl from those wetland surface-water systems for much of their food supply. The Lovelock lifestyle is characterized by an intensive lake-sink-marsh adaptation, with the use of caves and rockshelters surrounding lakes, sinks, and marshes, and a suite of distinctive artifact types, including basketry (Grosscup, 1960).

In the following, we use distinctive three-rod-foundation coiled basketry and Lovelock Wickerware basketry as hallmarks of the Lovelock Culture which define their approximate tenure in the western Great Basin.

More than 1000 fragments of Lovelock Wickerware basketry were recovered from Lovelock Cave, Nevada. Originally, the wickerware probably was in the form of conical, burden baskets. Lovelock Wickerware is known only from the Humboldt Sink, Pyramid and Winnemucca lake basins, the Carson Desert, and, possibly, Dixie Valley in western Nevada (Fig. 6).

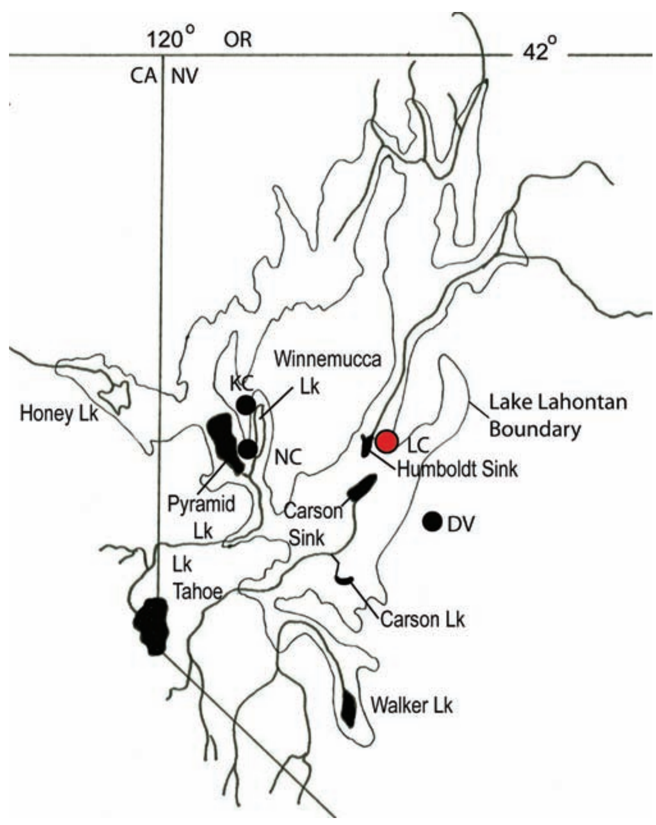
There are relatively few direct dates on Lovelock Wickerware, but existing dates range from 1573±200 BC to AD 1336 ±38 (Tuohy and Hattori, 1996). All radiocarbon dates on Lovelock materials have been calibrated using CALIB 5.01 (Stuiver et al.,1998). The ± value indicates the most probable age range and the number preceding the ± value indicates the midpoint of the range which we assume to be the most probable age of the object. Recently, Benson et al. (2007) dated an additional five Lovelock wickerware samples. All had calibrated ages that fell within the existing age range.

Figure 5
Mono Lake tree stump calibrated ages
Calibrated radiocarbon ages of exposed tree stumps from the Mono Lake basin. Radiocarbon data were taken from Stine (1994). Open rectangles surround times when trees were probably killed by rising lake water. Data indicate drought terminations at about AD 1370, 1300, and 1150. The probability of the 1-sigma age range is given by the number over the symbol. Symbols surrounded by a circle indicate the highest probability range for a single calibration. Vertical axis used to separate data groupings.



Coiled basketry initially appears in western Nevada around 2233±28 B.C. and persists until at least A.D. 1265±14 (Hattori, 1982). The latter date was recently obtained on a coiled, willow water bottle from Lovelock Cave. Therefore, the dates for Lovelock Wickerware and three-rod coiled basketry suggest that the Lovelock people occupied parts of the western Great Basin between about 2200 B.C. and about A.D. 1300. We do not have enough Carbon-14 ages on Lovelock Wickerware and three-rod coiled basketry to determine whether the middle-12th century drought impacted the Lovelock population. However, the disappearance of these textiles during the late-13th century drought suggests that the Lovelock Culture collapsed as a consequence of that drought and that the Lovelock people left the western Great Basin.

Figure 6
Location of some Lovelock rock shelters in the western Great Basin.
The location of Lovelock Cave (LC) is denoted by a solid red circle. Locations of Nicolarsen Cave (NC), Kramer Cave (KC), and Dixie Valley (DV) are denoted by solid black circles.



Impact of drought in the Four Corners area

The middle-12th and late-13th century droughts were most intense in the Four Corners area (Fig. 2). The reconstructed summer PDSI for the San Juan Basin (Fig. 1C) indicates that drought impacted the region during most of the time from AD 1130 to 1300.

The link that connects drought and Anasazi migration is maize. Maize was introduced into the southwest ~2240 B.C. and, over time, it became the dietary staple of the Anasazi inhabiting the Four Corners area. In the early historical period, The Hopi and the Zuni attempted to keep a second year's supply of maize in reserve (see e.g., Stevenson, 1904). However, such a reserve would not have been sufficient to last through a multi-year drought.

Maize yields are a function of climate and the properties of the soil in which the maize grows. We do not know the environmental requirements of maize grown by the Anasazi; therefore, we must rely on the requirements of modern forage corn and maize grown by present-day Pueblo people as a proxy. We suggest that Zuni and Hopi agricultural practices are good analogs for Anasazi practices. The Zuni mitochondrial DNA haplogroup distribution is very similar to that of the Anasazi (Carlyle et al., 2000), indicating that the Zuni are descended from one of the Anasazi groups.

Maize is produced in areas that receive 25 centimeters (cm) of annual precipitation or 15 cm of growing season precipitation (Shaw, 1988); however, optimum maize yields occur where growing season precipitation ranges from 40 to 60 cm (Minnis, 1981) and where the freeze-free period exceeds 120 days (Shaw, 1988). At Zuni, May-through-September rainfall averages 15.8 cm and there is a 90% probability that a period of 112 days will be frost-free (Western Regional Climate Center, Desert Research Institute, 2004). Zuni maize cultivars take ~125 days to mature (Muenchrath et al., 2002), and Hopi blue corn requires 115 to 130 frost-free days (Bradfield, 1971).

Freeze-free probabilities and precipitation data exist for 66 sites in the Four Corners area. To determine the best areas for dry-land farming of maize, we assumed that 90 freeze-free days and 30 cm of annual precipitation must be equaled or exceeded. Growing season precipitation averages ~50% of the minimum annual precipitation in the 66 sites. Twelve of the 66 sites have precipitation and freeze-free conditions that permit dry-land farming of maize (Fig. 7), and all 12 sites lie on the periphery of the San Juan Basin (Fig. 8).

Figure 7
San Juan Basin mean annual precipitation vs. freeze-free days
Plot of mean-annual precipitation versus freeze-free days for weather stations in the Four Corners area. Note that about half (49 ± 8%) of the mean-annual precipitation occurs in the warm season (May through September).

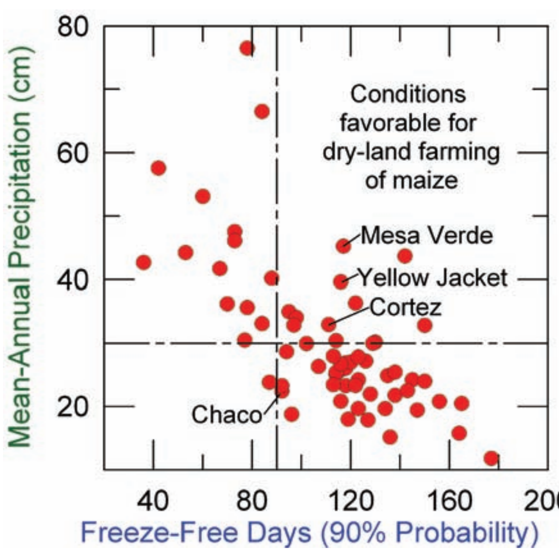


Figure 8
San Juan Basin dry-land farming areas
White circles indicate sites in which minimal dry-land farming can occur along the periphery of the San Juan Basin. Orange circles indicate locations of present-day Native Americans (Zuni and Acoma) that remain on the periphery; these people probably arrived at the periphery after the middle-12th or late-13th century droughts.

The impact of drought on the Anasazi

The Anasazi are thought to be the ancestors of present-day Pueblo people who occupy villages in New Mexico and Arizona. The emergence of Anasazi culture is generally associated with the introduction of pottery (at about AD 200 to 300) to an Archaic lifestyle that combined maize agriculture with hunting and gathering.

Over time, the Anasazi became more sedentary as witnessed by evolution in the form and size of their dwellings and villages. Early Anasazi were fairly mobile and tended to move every generation or so, and, in a sense, early pueblo people were nomadic agriculturalists. Between AD 700 and 900, Anasazi architecture took the form of surface pole-and-mud storage rooms constructed adjacent to circular or square-shaped pithouses. By AD 850, stone multistory structures (great houses) were under construction in the San Juan Basin (e.g., Pueblo Bonito; Windes, 2003). Construction of greathouses accelerated between AD 1050 and 1130, and by the end of this period over 207 great houses existed in the Four Corners region (Fig. 9) (Fowler and Stein, 1992; Kantner and Mahoney, 2000).

Thus, the changing architecture of the Anasazi can be interpreted to indicate a culture that evolved to a relatively sedentary agricultural lifestyle in which maize was a dietary staple. Stuart (2000) has estimated that between 10,000 and 20,000 farmsteads populated the Four Corners region by the late-11th century. This is not to say that the Anasazi did not forage in the 11th and 12th centuries but that agriculture dominated their subsistence base.

During the middle-12th century, most of the great houses in the central San Juan Basin were vacated and, during the late-13th century, most of the remaining great houses and many of the smaller villages in the Four Corners area were abandoned (Fig. 9). Great house construction and remodeling in Chaco Canyon ceased at AD 1130 (Vivian and Hilpert, 2002, p. 34). Tree-ring-dated habitation sites also indicate rapid population declines beginning at AD 1130 and 1280 (Fig. 10) (Berry, 1982). Anasazi groups that occupied lands in southwestern Utah, e.g., the Virgin River Anasazi, also abandoned their settlements during the middle-12th-century (Larson and Michaelsen, 1990; Lyneis, 1996).

A comparison of the locations of the 12 weather station sites that permit dry-land farming with locations of great houses occupied after the drought of AD 1150 (Figs. 8 and 9) indicates a measure of congruency, suggesting that the Anasazi may have been forced to leave the relatively cold and dry central San Juan Basin during the drought because that area was no longer able to support dry-land farming. Two of the Native American cultures that stayed in the Four Corners area after the middle-12th and late-13th century droughts (The Zuni and the Acoma) remain on the periphery of the San Juan Basin (Fig. 8).

Some authors have argued that the abandonment of farming was in response to a deterioration of climate (e.g., Hunt, 1953; Rudy, 1953). Lindsay (1986) and Newman (1996) suggested that reduced summer moisture and a shortened growing season (e.g., Salzer, 2000) were the specific causes of agricultural failure, and that the change in climate was due to a shift in the northern boundary of the summer monsoon which today reaches only into southeastern Utah (Mitchell, 1976). This concept is consistent with Petersen's (1994) suggestion that that the expansion of piñon in southwestern Colorado during the 10th and 11th centuries was due to an increase in summer moisture. These studies imply that, prior to AD 1130, the summer monsoon was stronger and its boundary lay north of its present-day position, allowing the Anasazi to expand their territory and increase their population, during a time when maize yields were relatively high.

Fig. 9 Great House abandonment
Great house locations throughout the Four Corners area. Those houses represented by green squares were abandoned before AD 1150 and those represented by yellow triangles were abandoned by AD 1300.

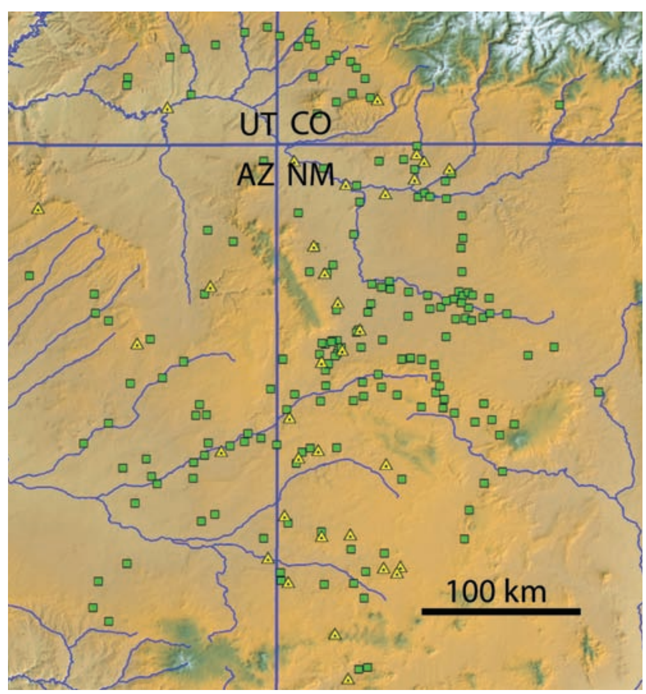
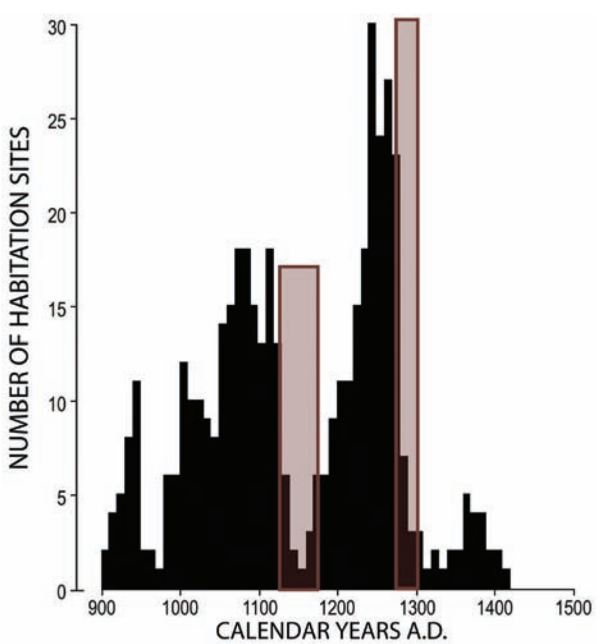


Fig. 10 Four Corners habitation
Number of tree-ring dated habitation sites from the Four Corners area (Berry, 1982). Habitation site number should be considered only a rough nonlinear measure of habitation. Vertical gray-bounded rectangles delineate the middle-12th and late-13th century droughts.



Between AD 1050 and 1130, accelerated great-house construction occurred across the Four Corners area, including six new great houses in Chaco Canyon. By A.D. 1130, over 207 great houses populated the Four Corners area (Fowler and Stein, 1992). In the middle-12th century, an intense and persistent drought affected much of the contiguous United States. This drought led to massive Anasazi habitation-site declines; e.g., 85 percent of the great houses in the Four Corners area were abandoned, and the late-13th century drought saw the abandonment of the remaining great houses and habitation sites in the Four Corners area.

The droughts of the middle-12th and late-13th centuries probably included both winter and summer drought. This is consistent with the tree-ring study of Fritts et al. (1965) who found that the Great Drought was associated with reduced winter and summer precipitation and elevated summer and autumn temperatures. The middle-12th and late-13th century droughts occurred after population expansions, during a time when people were living at the limit of their environmental and agricultural support systems (Dean et al., 1985; Dean, 1988). Some of the droughts persisted for several years and would have caused all surplus maize to be consumed, thereby forcing the Anasazi to migrate to more agriculturally productive areas.

This concept is reinforced by the work of Burns (1983) who reconstructed maize and bean yields in southwestern Colorado using tree-ring records. Burns (1983) showed that, given a 1.5-year storage capacity, the harshest famines endured by the Anasazi occurred during the middle-12th and late-13th centuries.

The precipitation-dependence of these groups appears to have brought about their demise. In some sense, the two droughts acted as a slow-motion, one-two punch with the first blow putting the cultures on their knees and the second blow ending the fight.

Summary

We have examined evidence of the decline of two prehistoric Native American groups: the Lovelock and the Anasazi Culture. The Lovelock were hunter-gatherers who relied heavily on flora and fauna found in western Great Basin marsh environments. The Anasazi relied on maize horticulture as a principal part of their subsistence base. Thus, both groups relied on resources which were precipitation dependent.

Little or no data exist with respect to Lovelock population dynamics other than the intensive use of caves for caching material culture when compared with preceding and subsequent occupations. However, it would appear that the introduction of horticulture allowed the Anasazi population to increase during times of abundant precipitation. In fact it might be argued that, not unlike existing nation states, these people did not encourage a memory of bad times but allowed their populations, in good times, to expand to the limit of their resource base. We have no data on the response of the Lovelock to the middle-12th-century drought; however, during the subsequent late-13th-century drought, the remnant of the Lovelock culture appears to have abandoned their former homelands.

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